DSN Technology Program News

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SPACECRAFT COMMUNICATIONS

Small Deep Space Transponder Development

Sam Zingales

A contract for development of a new deep space transponder was initiated with Motorola in July 1995. The transponder, a device mounted on board the spacecraft, is used to receive the DSN's uplink signal and to generate the downlink signal to the DSN. Spacecraft commands contained on the uplink are demodulated and provided to the spacecraft's Command and Data Handling Subsystem. Conversely, engineering and scientific data supplied by that subsystem are modulated onto the downlink.

A transceiver, a device capable of simultaneous reception and transmission, could be used to perform the command detection and telemetry modulation functions described above. A transponder is needed because of one other important operational requirement; namely, that the transmitted signal be derived from the received signal. This relationship, often referred to as coherency between transmitted and received signals, enables derivation of two-way Doppler. This information assists in determining spacecraft location and flight navigation.

Recognizing the need for a new, small deep space transponder (SDST) offering lower size and power and, most importantly, lower production costs, a consortium of JPL sponsors (including TMOD, SESPD, TAP, and the Mars Exploration Program Office) has come together to fund the development of this critical item. Aimed at enabling future low-cost microspacecraft, its design will feature X-band uplink (frequency about 7150 MHz) with X-band (~ 8400 MHz) and Ka-band (~ 32,000 MHz) downlink capabil-

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In This Issue

Laif Swanson

This issue of the DSN Technology Program News has four articles: two about spacecraft communications systems and two about ground antennas; all make spacecraft communications cheaper; most also make spacecraft communications better and development faster.

Sam Zingales, leader of the Small Deep Space Transponder development team, talks about this device, which will change in the cost, power, and weight associated with communications. The ideas being used were largely developed in the Spacecraft Communications Systems work area of the DSN Technology Program, which is managed by Lance Riley. Steve Lichten, manager of the Radio Metric Tracking work area, talks about microGPS, an ultra-low-cost means for acquiring GPS signals on board Earth orbiting spacecraft for orbit determination.

On the subject of ground antennas, Javier Bautista describes the movement toward using HEMTs as a low-cost alternative to expensive and hard-to-maintain ruby masers as low-noise amplifiers. Javier leads the Low Noise Systems work area. Figuring out how to integrate these new HEMT low-noise amplifiers into the DSN, and ensuring they work even while simultaneously transmitting a high-power uplink, is the subject of Mark Gatti's article on diplexing. Mark manages the Antenna Systems work area.

ity. The X-band downlink frequency, when locked to the uplink, is 880/749 times the uplink frequency; for Ka-band this "turn-around ratio" is 3344/749.

The command detection (CDU) and telemetry modulation (TMU) functions will be built-in, as will project selectable standard bus interfaces for monitoring and controlling the transponder. The command and telemetry interfaces remain hardwired interfaces to the Command and Data Handling Subsystem.

The development has three major milestones:

(a) An interim proof-of-concept review presenting the system design and supporting analyses along with RF breadboard performance results. This review was held in November.
(b) A final proof-of-concept review presenting carrier tracking results from the system breadboard in April 1996.
(c) Delivery of an engineering model unit in late 1996.

The first New Millennium mission plans to fly the SDST engineering model in the 1998 time frame.

The Motorola-proposed design features four technologies new to deep space transponders. First, a digital receiver architecture is employed, based on the current Cassini deep space transponder (DST) frequency scheme. This leverages off design technologies and implementations used in past JPL transponders and other Motorola flight transponders and communications packages. Although conservative in approach, it is key to meeting the SDST development schedule and cost constraints.

Second, Microwave Monolithic ICs (MMICs) will be used in RF circuit applications, wherever possible. Parts selection must assure SDST availability in the future and achieve the specified performance and reduced production costs.

Third, several MMICs will be packaged into a single Multichip Module (MCM) employing low temperature cofired ceramic (LTCC) substrates. The LTCC technology results in a multilayer RF printed circuit board allowing RF components and circuitry to be buried within layers. For the SDST, only nonactive devices such as couplers and power dividers will be buried to minimize development risk. Use of MMICs and the MCM technology is critical to meeting the mass requirements.

Last, an Application Specific Integrated Circuit (ASIC) will be used to perform the digital signal processing functions. A RISC microprocessor will be used with the ASIC to orchestrate overall transponder operation.

Besides minimizing production costs, the principal design drivers are the mass (2.5 kg target, 2.0 kg goal) and power (<10 W X up/X down without the bus interface). Although not specified, volume will be reduced significantly from that of the current deep space transponder simply because of the reduced mass requirement. This is particularly true when considering that the SDST will include the current CDU and TMU functionality.

Achieving significantly reduced production costs while maintaining the required reliability and quality will be a considerable design challenge. Currently, deep space transponders cost in excess of $2 million. From the outset, the SDST design will be directed toward reducing manufacturing costs. All areas and factors will be considered including parts selection, fabrication, assembly, integration and test costs. Of these, parts costs are believed to be key. It is imperative that relationships be established with reputable suppliers in order to minimize lot and screening charges. The SDST per unit production costs are targeted for less than $750 K with a goal of $500 K in lots of five or more.

RADIO METRIC TRACKING

microGPS: Low-Cost, Orbit Determination

Stephen M. Lichten

The Jet Propulsion Laboratory (JPL), and the University of Colorado (Laboratory for Atmospheric and Space Physics [LASP] and the Colorado Center for Astrodynamical Research [CCAR]) have joined together to design, build, integrate, and test a microGPS instrument for inclusion on the NASA-funded Student Nitric Oxide Explorer (SNOE) spacecraft. This is the first step in a logical progression toward the development of a fully autonomous, ultra-low power Global Positioning Satellite (GPS) space receiver. This new GPS space receiver is envisioned as ultimately costing a few tens of thousands of dollars per unit (fully hardened), requiring less than 0.01 W average power, and having mass of a few hundred grams. The instrument is scheduled for completion at the end of FY96.

The microGPS receiver should be capable of providing real-time orbit knowledge to the level of a few hundred meters for most low-Earth orbiters. Operational costs would be essentially zero because all receiver functions, including data processing and orbit determination, will be completely automated. Such an instrument could play a key role in implementing the new NASA philosophy of minimizing operations costs and simultaneously supporting large numbers of very small satellites at very low cost. For these satellites, instrumentation will be miniaturized and likely to consist mostly of a collection of chips. This is essentially what the microGPS instrument consists of, with the largest component being the patch antenna that is a few cm in diameter (see Figure 1).

1. SNOE: The First Step

The SNOE mission will include measurements of nitric oxide, which plays an important role in the thermal balance of the atmosphere. Nitric oxide also reacts chemically with ozone. There are many unanswered questions about how the chemical balance of the atmosphere and how abundance measurements can explain some of the global thermal trends being observed.

SNOE launch is anticipated in March 1997. This microGPS receiver will include: a small, lightweight GPS patch antenna; a downconverter and signal sampler; and a memory interface chip (Figure 1). GPS data will be sampled only once every hour or so, with each sample covering only a few milliseconds. Because the microGPS is thus actually "on" only a tiny fraction of the time, the average power consumption will be much smaller than 1 W. For SNOE, in part to minimize the cost of the experiment, the raw GPS data bits will be stored onboard and sent down to the ground with other spacecraft telemetry. The processing of these raw data will occur in two main steps. First, the raw bits will be converted into actual GPS observables (pseudorange, phase, and Doppler). This requires some knowledge of the GPS broadcast message, which is easily provided from other GPS receivers; for SNOE the GPS broadcast message probably will be retrieved over the Internet from JPL or from one of dozens of receivers available. Second, the GPS observables will be analyzed to estimate the position and velocity of the spacecraft.

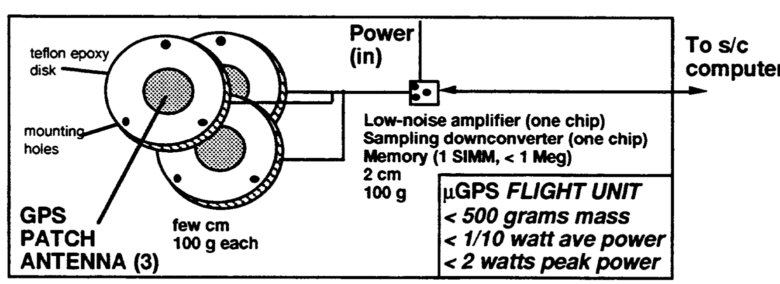

Figure 1. The microGPS Bit Grabber GPS Space Receiver. Three patch antennas are needed for attitude determination; only one for orbit determination.

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